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Comparative applications of simple and complex faculty flow models are examined to determine (1) their relative demands for data and calculations, (2) the divergence of their projections, especially when modelling a no-growth faculty, and (3) an estimate of the error incurred (i.e., the cost to analysis) when a simple model is used. The results support the view that academic personnel policy changes have delayed effects and are nonlinear. It is suggested that simple models may mislead analysts by being insensitive, for example, to backlogs of term appointees who expect promotion. Similarly, it may be that no model is needed at all if one is only looking for estimates on a two-year horizon. (Author/SW)

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COMPARATIVE EFFICIENCIES IN PROJECTING FACULTY RANK DISTRIBUTION

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Mary Corcoran
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ABSTRACT

Comparative applications of simple and complex faculty flow models are examined to determine (1) their relative demands for data and calculations, (2) the divergence of their projections, especially when modelling a no-growth faculty, and (3) an estimate of the error incurred (i.e., the cost to analysis) when a simple model is used. The results support the view that academic personnel policy changes have delayed effects and are non-linear. The comparison indicates that simple models may mislead analysts by being insensitive, for example, to backlogs of term appointees who expect promotion. Similarly, it may be that no model is needed at all if one is only looking for estimates on a two-year horizon.

FACULTY FLOW MODELS

Two basic characteristics determine the structure of a faculty flow model: 1) the sets of rank and/or appointment durations used as an organizing framework; and, 2) the form of the mathematical linkages between the sets across time. Three general structures have been used in earlier research:

a) percentage point increases (e.g. von Zur-Muehlen, 1977, 1979);

b) equilibrium models (e.g. Oliver, 1969; LaSalle, 1972, Higbee, 1975); and,

c) Markov chains (Bartholomew, 1969; Schroeder, 1974; Hopkins, 1974; Goveia, 1976; Bloomfield, 1976).

Another method of projecting faculty rank distribution assesses the likelihood of a change in rank or appointment for each individual faculty member and sums all the transactions into a new distribution (see, for example, Linnell, 1976). This Monte Carlo technique does not relate distributions across time and will not be considered further, although it is useful to note that, in comparison with a Markov chain, ". . . both methods arrived at remarkably similar results." (Goveia, 1975).

Percentage Point Increase Models

The most simple technique has been applied to data summarizing all the universities in Canada (e.g., von Zur-Muehlen, 1977). The approach examines the rates of historical growth or decline in relative proportions of total faculty for each of four academic ranks. Projections are based on a constant growth in the percentage of the professoriate holding the rank of Full Professor and Associate Professor (e.g. 0.8% per annum and 1.5% per annum, respectively) with associated declines in the percentage of Assistant

Professor and the Rank Below Assistant (e.g. -1.7% per annum and -0.6% per annum, respectively). In the national example, the sum of the declines and increases was set at zero on the assumption of no increase in the overall size of the professoriate population.

Algebraically, the percentage change approach may be expressed:

$$\left(\frac{N_i}{N}\bigg|_{(t+1)}\right) \times 100\% = \left(\frac{N_i}{N}\bigg|_{t}\right) \times 100\% + P_i$$

Where:

N_i = the number of faculty holding appointment at rank i

P_i = a fixed percentage rate of growth for the population holding rank i

Such that:

$$\sum_i N_i = N \quad ; \quad \sum_i P_i = 0$$

and, for no growth:

$$N_{(t+1)} = N_{(t)}$$

Attending to the historical proportion of appointments at each rank ignores the question of duration of appointment and thereby linking one distribution to a later version does not address any of the transition details incorporated into equilibrium or Markov models. The relative size of rank populations uses the most simple combination of concepts and mathematically is the simplest of the three classes of models.

Equilibrium Models

Equilibrium models link a small number of cells, usually three or four, with a modest number of input and output and transition paths among them. For example, Oliver (1969) does not incorporate any rank variables, but uses two cells, based on the tenure/non-tenure distinction, plus a cell for

retiring faculty in conjunction with a total of seven paths. Similarly, LaSalle (1972) uses a three-cell format, with the three professorial ranks as cell identifiers, and incorporates nine possible pathways.

An application of equilibrium modelling to a Canadian institution was made at McMaster University (Higbee, 1975; Pardasani, 1972). The McMaster framework was developed from a slightly more complex formulation, but in final form uses four rank-only cells and twelve pathways (see Figure 1). It provides for hiring of new staff at each rank (H_i), promotion through the ranks (P_i), separation through death or resignation from each rank (T_i) and retirement from the rank of Professor (R).

INSERT FIGURE 1 HERE

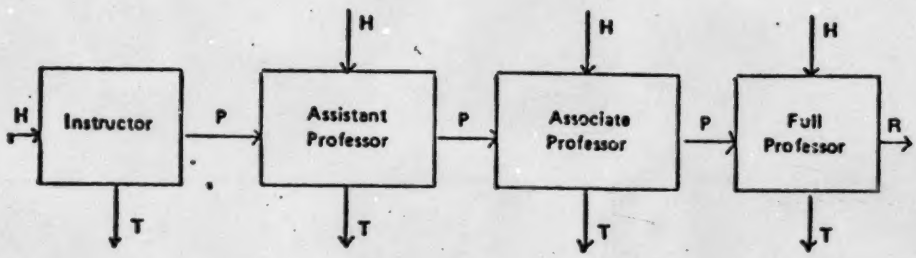

Figure 1

A Four Stage Equilibrium Flow Model (Higbee, 1975)

In all cases, the equations linking rank distributions at any initial time (t_o) and a later time (t_i) use historically determined rates of promotion and separation in conjunction with actual cell populations at t_o to project the base populations forward one time unit, usually one year. Under the equilibrium assumption implied in the name of these models, the total target distribution at t_i is equal to the total distribution at t_o, i.e., the faculty does not grow.

Application of equilibrium models has indicated that, for example, ". . . extrapolation of current Berkeley data to the years 1975-80 where we expect equilibriums to set in indicates that there are no feasible equilibria for current appointment policies" (Oliver, 1969:3). "The general message provided by analysis with equilibrium models seems clear enough, however, there may be problems with their precision" (Hopkins, 1974).

Markov Chain Models

Superior modelling of faculty rank or appointment distributions is reported to be possible by defining ". . . the states (i.e., categories of faculty members) in a way that is both useful for analyzing changes in policy and meaningful as a description of individual behavior" (Hopkins, 1974:400). This in turn requires more states than used in equilibrium models, and more transitions such as ". . . service-dependent promotion rates for non-tenure faculty, . . . and the rank distribution of new appointments" (Hopkins, 1974:401).

Multiple states can be accommodated readily in Markov-chain models in which the appointment distribution at t_i is dependent on the distribution

at t_o and the two distributions are linked by a set of transition probabilities (Draper and Klingman, 1967). Brown states the key assumptions of a Markov chain when applied to the movement of personnel:

1. The Markovian axiom states that an individual's past history has no impact on his future movement except through the status that he presently occupies. Its main function is seen as a simplifying one since a model which acknowledged the unique history of every individual would be extremely complex.
2. The independence assumption states that moves on the part of one individual are made independently of moves on the part of others.
3. The homogeneity assumption states that all persons are alike in terms of their propensity to move.
4. The stationarity assumption that states that the probabilities of movement from one status to another do not vary over time. Since it must be acknowledged that no perfectly stationary process exists, this axiom must be regarded as an idealization. (Brown, 1975:145 and 146).

The independence assumption may be accepted since universities do not require a change in rank or duration of appointment to be contingent upon any change for another individual (Michaels, 1974), hence, those changes may be considered to be independent. On the contrary, the traditions and practices of universities place considerable stress on promotion and tenure being related to the individual (CAUT, 1979). However, the application of tenure or rank quotas would cause this assumption to be violated.

One of the earliest applications of a Markov transition matrix was by Rowe, Wagner and Weathersby (1970), as part of the Ford Foundation's program of research in university administration. Hopkins (1974, 1975) applied a Markov model to two schools within Stanford University. The Stanford model was based on a 17-state transition matrix being made relatively simple by the relative uniformity of university policy concerning academic appointments (Bloomfield, 1975). The model does not address rank as a variable, a reasonable approach since new appointments at Stanford are normally at the rank of Assistant Professor, and since promotion to Associate Professor generally coincides with aware of tenure. Such conditions do not universally apply to public universities, neither in Canada nor in the United States. (Bolte, et. al., 1977).

To extend the Stanford framework in applying Markov models to a more complex policy environment, Bloomfield (1976) compiled a 161-state Markov matrix to represent the entire Oregon State University. (See Table I).

INSERT TABLE 1 HERE

Table 1

University Comprehensive Faculty Flow Model

State Definitions for the Oregon State

(Bloomfield, 1976)

Variables	Categories	Number
Tenure Status	Nontenured, Tenured	2
Rank	Instructor, Assistant professor	
	Associate professor, Professor	4
Years in Rank	0-3, 4-6, 7-9, 10+	4
Age	0-39, 40-49, 50-59, 60+	4
Years of Service	0-3, 4+	2

The Bloomfield study produced, as did equilibrium studies, curvilinear projections of faculty mix proportions. They differ from the simple linear projections derived by the percentage-point increase technique, but require much more information in many more categories. In short, the data requirements for projecting faculty rank distribution increase significantly as one considers percentage point, equilibrium flow and Markov chain techniques in turn.

Summary of Faculty Flow Models

Three kinds of analytical models have been used to project distributions of academic rank of appointment from aggregate data and may be summarized in terms of 1) the concepts used to categorize appointments; and, 2) the form of the mathematical relationships employed (see Table II).

INSERT TABLE 2 HERE

Table 2

A Summary of Faculty Flow Models

Model Type	Categorization Method		Mathematical Relationships		
	Number of Variables	Basic Concepts	Number of States	Number of Relations	Form of Relations
Percent Growth	One	Rank	Low (4)	Low (4)	Proportional Change in State Size
Equili-brium	One	Rank or Tenure	Low (3-10)	Low (3-10)	Inter-state Flow Rates
Markov	Four or Five	Rank Duration Tenure Age Service	High (17-161)	High (17-161)	Transition Probabilities

The summary table shows that two of the three types of model (i.e., percent growth and equilibrium) are based on a single variable for categorization and use small numbers of states in combination with small numbers of equations to relate rank or tenure distributions across time. In contrast, the Markov models use larger numbers of variables with many more states, the number of relationships is, therefore, also much larger. On the basis of Hopkins' criterion of meaningfulness, the Markov model should produce the highest quality projections.

Notwithstanding methodological differences, the conclusions of most studies focus attention on the 5 to 10 year horizon and agree, in general, that there are problems ahead in managing faculty rank distribution. No comparative assessment of projections developed by the various methods shows to what extent they differ. Similarly, the various methods each require different amounts of data and calculation. Therefore, it is not clear whether (a) common conclusions apparently are reached on the basis of what could be substantially different findings, or (b) what economy of modelling is possible if one wants, for example, to find out "What would happen if. . .?" on a particular campus, and is faced with choosing a method to forecast faculty rank distribution.

A COMPARATIVE APPLICATION

Three sets of ten-year projections were made using a common set of historical data and processed by each of the three techniques outlined above. As a benchmark projection, another set of projections was made as a simple linear extrapolation of faculty rank sub-populations. That simple set (Method 1) is included to illustrate what could be done without using <u>any</u> model to link the elements of faculty rank distribution.

The first "model" used the intermediate assumptions laid out by Holmes and von Zur-Muehlen (1979), and noted on page 2 in projections with constant percentage changes in the proportion of the professoriate. It is reported here as "Method 2". The next set used a straightforward application of Higbee's (1975) four-stage equilibrium model (Method 3). Finally, an adaptation of the Bloomfield schema was used to model the future progression of tenured faculty and up to 21 cohorts of faculty hired on term appointments. (See Figure 2). That set is reported here as Method 4.

It is important to note that all four techniques can be evaluated against a criterion of fit to history; i.e., take 1975 and project 1980. That test is not sufficient for determining relative strengths in future forecasting because a) fitting a model to historical data and then projecting historical point is tautological; and, b) more important, the problem of determining the effects of pressure to promote in a faculty which is frozen in size represents a non-trivial break with history. Therefore, fit to history is irrelevant. With that in mind, to provide any criterion measure for comparison, the Markovian approach is chosen since it provides theoretically the most sensitivity.

Extracts of the results of the comparative applications* are shown in Table III "Alternate Ten-Year Projections of Faculty Rank Distribution". Note that Methods 2, 3 and 4 are no-growth projections. To compare the four, percentage deviations from the "cadillac" projection (using Method 4) for each of the other three models are shown graphically by rank in Figure 3.

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*Full statistical tables are available from the author.

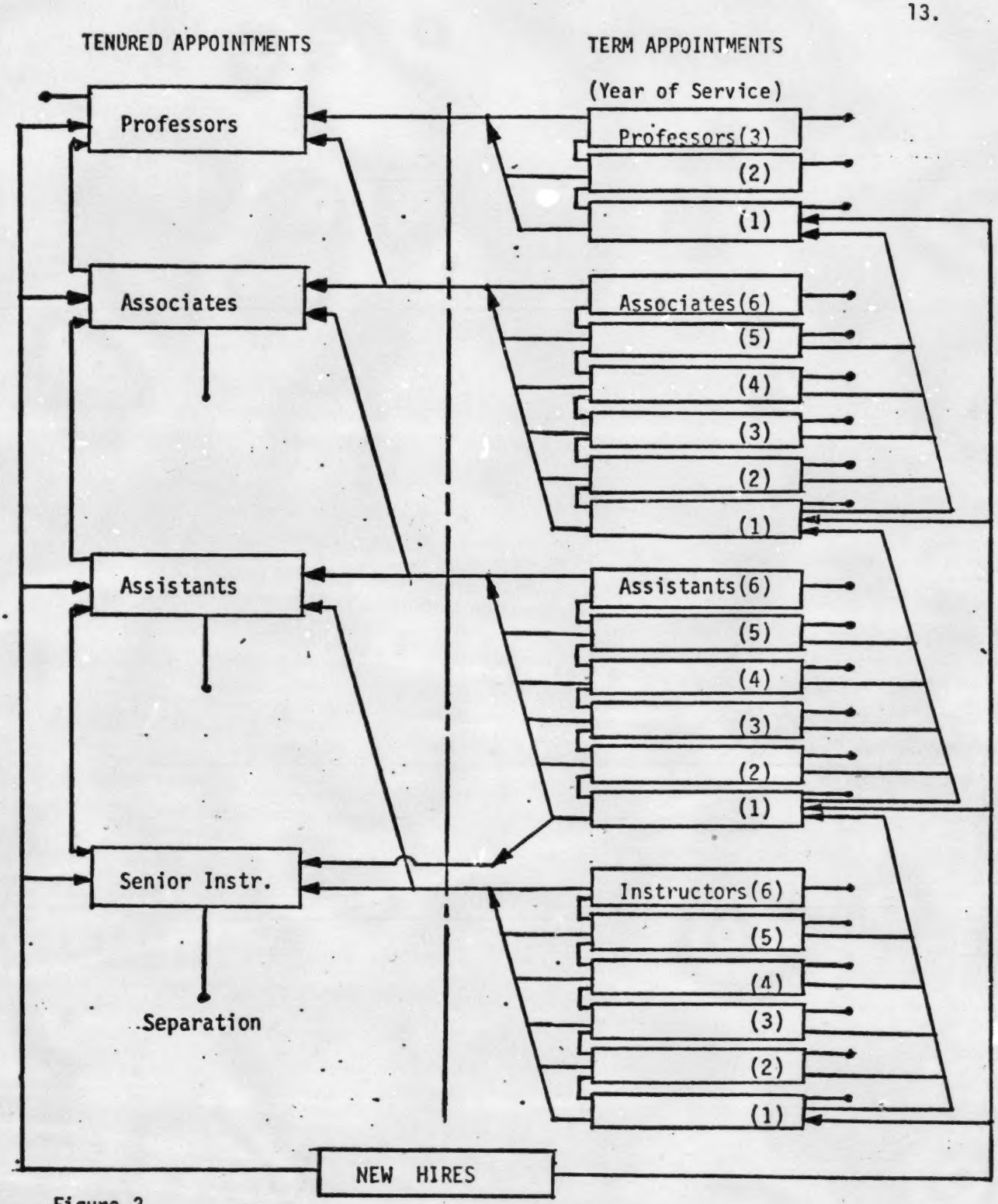

Figure 2

A Comprehensive Categorization Framework

TABLE 3

ALTERNATIVE TEN-YEAR PROJECTIONS OF FACULTY RANK DISTRIBUTION

-SELECTED YEARS-

[Normalized to N=1000 at t=0]

	RANK	YEAR 1	YEAR 4	YEAR 7	YEAR 10
Method 1					
Linear projection	1	285	332	378	424
	2	320	366	414	462
	3	334	315	295	275
	4	76	74	73	72
	Σ	1 015	1 087	1 161	1 233
Method 2					
Percentage change	1	281	305	329	351
	2	319	364	409	454
	3	325	274	223	172
	4	75	57	39	21
	Σ	1 000	1 000	1 000	1 000
Method 3					
Equilibrium flow	1	288	321	352	378
	2	316	334	338	333
	3	319	275	246	228
	4	77	69	64	61
	Σ	1 000	1 000	1 000	1 000
Method 4					
Markovian	1	288	333	373	390
	2	306	308	289	271
	3	329	293	273	271
	4	77	66	65	69
	Σ	1 000	1 000	1 000	1 000

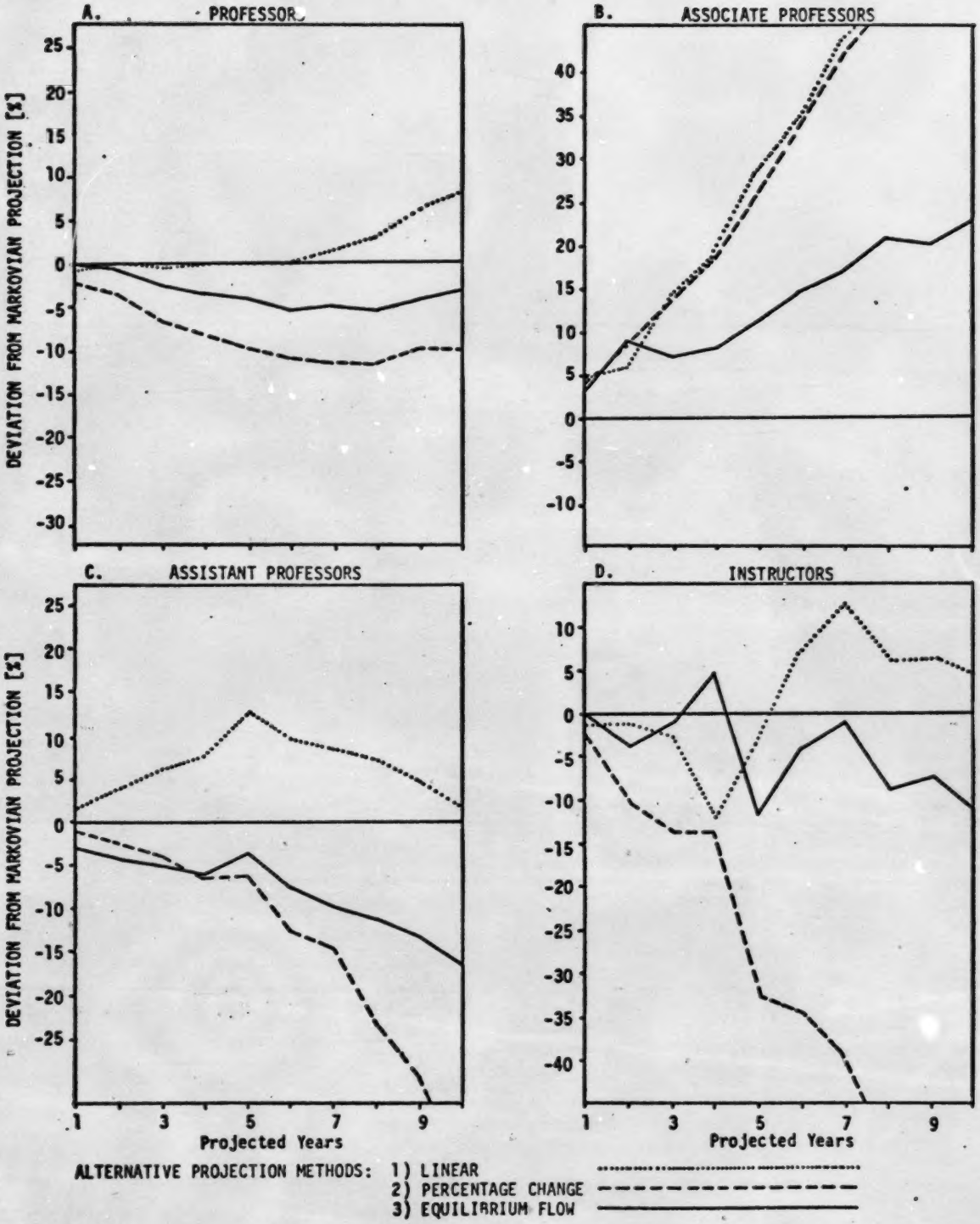

Figure 3

Percentage Deviation From Markovian Projection

by Rank and Projection Method

From Figure 3A, the relative stability of the projections for the Full Professors is clear. Indeed, the Markovian projection is nearly linear for six years, at which time the reduced hirings begin to drive it away from a straight line. As would be expected, the equilibrium model is closer to the Markovian than is the percentage change technique, with about half the error, indicating that attention to length of untenured service, etc., has only a modest effect on this tenured group.

Figure 3B shows that the methods diverge greatly from Associate Professors. In the second year, almost 10% deviation is present, and even the equilibrium model drifts at a rate of roughly 2 1/2 percent per year. The simple percentage change model diverges strongly from the Markovian, revealing that reduced hiring and promotion will influence the Associate population much more than expected in the simple view.

The projections for Assistant Professors (Figure 3C) show a clear discontinuity in the fifth year. After that time the present cohorts will be completely replaced by individuals hired under the no-growth scenario and change in size of the Assistant population will become more linear. That means that methods which are insensitive to cohort or length of service deteriorate in their ability to predict the Assistant population after the fifth year.

Finally, Figure 3D shows that no other technique is very close to the Markovian after a year or two projecting Instructors. The percentage decline model is almost immediately at a large disadvantage, and the equilibrium flow model is erratic at best. Of course, the population of Instructors is small and is highly sensitive to short-term changes in personnel needs.

Summary

This paper points out conceptual and technical differences among three kinds of methods used to project faculty rank distributions. Many studies conclude that faculty mix will be troublesome. This paper would indicate that some simple projections may understate the problem, for example with respect to Associate Professors, and may reach conclusions that to some extent are an artifact of their methodology.

Over a short horizon, say two years, a simple linear projection of faculty members appears to be at least no worse than simple models, and because of its great economy, may be a critical competitor with them. However, the value of two-year projections must be limited when one is concerned with appointment policies that have implications over a thirty year period, and take up to ten years to show response to change.

Based on the comparative application of three techniques to various combinations of one set of historical data, it seems that relatively simple techniques are potentially misleading. For example, the serious deviations between Markovian and simpler techniques over longer horizons indicate that the cost to analyze may be so great as to render their use inadvisable.

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